

Human Robotic Cooperation

using humans and robots synergistically to explore
the solar system



Scenarios

Geoffrey A. Landis

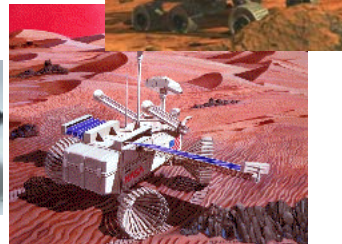
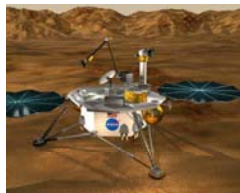
NASA Glenn Research Center

<http://www.sff.net/people/geoffrey.landis>



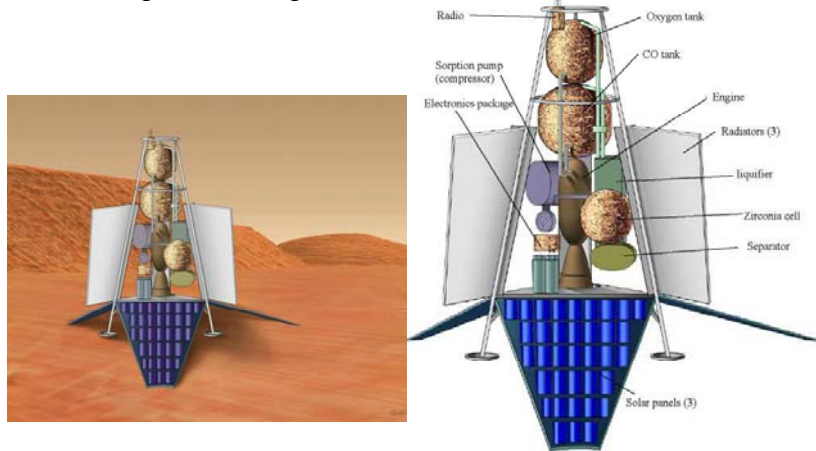
Mars Exploration

- Robotic precursors for human exploration
 - Learning about how to operate on Mars
 - Selecting site for human mission
 - Demonstration of critical technology
 - Fuel manufacture before human presence



Robotic “hopper”

rocket-powered explorer refuels from Mars atmosphere



Landis and Linne, *Journal of Spacecraft and Rockets*, Vol. 38 No. 5, 2001

Robotic hopper flight profile

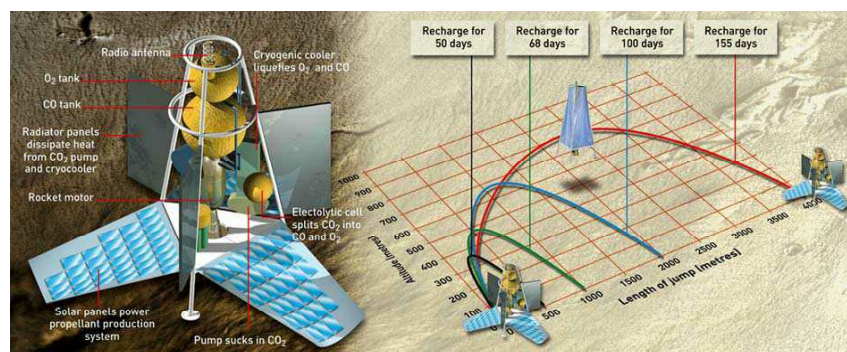


Image courtesy *New Scientist* magazine

Robots assisting humans on Mars

- Aerial reconnaissance to plan traverses and locate exploration targets
 - Satellite recon
 - Aerial vehicles
- Robotic “mule” to follow astronauts: hold tools and carry samples
- Robots to do “grunt work” of science: setting out remote instrumentations, solar array deployment and cleaning, etc.
- Robotic long-range rovers take driving burden off of astronauts

Mars solar-powered scout airplane



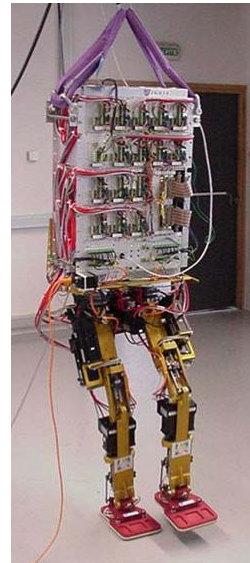
- 10 kg-- hand launchable
- Camera allows aerial views of local area to plan exploration
- Real-time updating “what’s going on”
- PR views

Robots to **replace** **humans** for EVA

- Humans remain in habitat:
**let remotely operated
Telerobots do the exploration**



Honda P3
advanced
bipedal
robot



BIP-2000 bipedal robot project

“Robonaut” telerobot for space station

“Robonaut” telerobot



Robotic arm hardware

Why telerobots?

- Lowers risk-- allows dangerous exploration
- Allows exploration beyond “walk-back” distance
- reduces EVA load
- Robots have expanded senses (radar, infrared, gamma-ray eyes)
- Samples analyzed by humans in lab on-site
- For interesting sites, initial forays by telerobots can be followed by detailed visit by humans
 - Save the humans for goal-oriented exploration once you know exactly where and what



What safety committee will approve cliff-climbing in Valles Marineris?

A radical proposal: Human Exploration from Mars Orbit

- Don't land the humans on the surface, but explore via telerobot from orbit
 - Teleoperation from orbit allows near “real time” operation with minimum time delay
- No need to develop Mars Lander and Mars Ascent Vehicle
 - Send geologists & biologists; not VTOL pilots
- Cheaper, simpler, and safer way to explore
- High human engagement factor (kids are excited by video games, robots, and virtual reality)
- All the excitement of being there, at a fraction of the price

Tele-Exploration from Mars Orbit

more advantages

- Human (virtual) presence at a **wide variety** of locations
- Not stuck with one base location; explore all over Mars
 - Explore the polar caps and also near-equatorial canyon regions
 - No need to select a “grab bag” site; go to **all** the best sites-- paleolake sites, river beds, volcanic calderas, lava tube sites, layered terrain, canyons, possible shoreline features, the North and South poles-- Mars is a huge planet, so why camp in just one place?
 - Near-polar exploration will need apolar orbit or an inclined orbit for surface teleoperation
 - Highly inclined 24-hr 39-minute orbit will put station in line-of-sight of a given region for about 8 hours per day-- one teleoperation shift

Why explore from Orbit?

Scientific rationale

- Keeps humans from contamination by Mars microbes
 - No quarantine on return to Earth
- Keeps surface of Mars sterile for biological quarantine
 - The most exciting question on Mars is: is there life?
 - Need to explore with no human contamination of Mars
 - All space suits are leaky!!
 - Preserve fragile Mars biosphere from competition from ferocious Earth life

Beyond Mars: Human Exploration of Venus by Telerobot

- Venus is a fascinating planet: “Earth’s evil twin”
 - Before the runaway greenhouse effect, was early Venus temperate?
 - Did Venus once have an ocean?
 - What causes the geological resurfacing of the planet?
 - What is the “snow” on Venus mountaintops? (certainly not ice!)
 - Can we learn about Earth’s climate from Venus?
- Too hostile to land the humans on the surface, but we can put humans in the atmosphere to explore via telerobot
 - At the one-bar pressure level, temperatures are fine-- 0 to 20 C
 - Lots of solar energy
 - CO₂ plentiful resource for life support, no pressure vessel
 - Oxygen and Nitrogen are lifting gasses on Venus.

Beyond Mars: Human Exploration of the Jupiter system by Telerobot

- Why stop at Mars and Venus?
Whole solar system is exciting!
- Explore Jovian moons
 - Humans need radiation protection
 - **expendable radiation-tolerant robots**
bring human presence into protected habs
 - Expand human exploration from the sulfur volcanoes of Io to the oceans of Europa
- Explore Jupiter’s atmosphere by
(tele-) nuclear ramjet

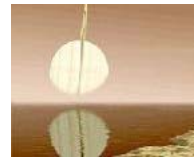


Pat Rawlings



Beyond Jupiter: Exploration of the outer solar system by VR

- Outer solar system is exciting,
but trip time is years to decades
- Let robots send back **detailed Virtual Reality models**
 - Humans can explore in the comfort of their own planet
 - Each robot sends terabits of data-- and send hundreds of robots
 - high-bandwidth laser communications
 - Technology for this is here
- Engage the entire population of Earth--
everybody can be an explorer!



Pat Rawlings

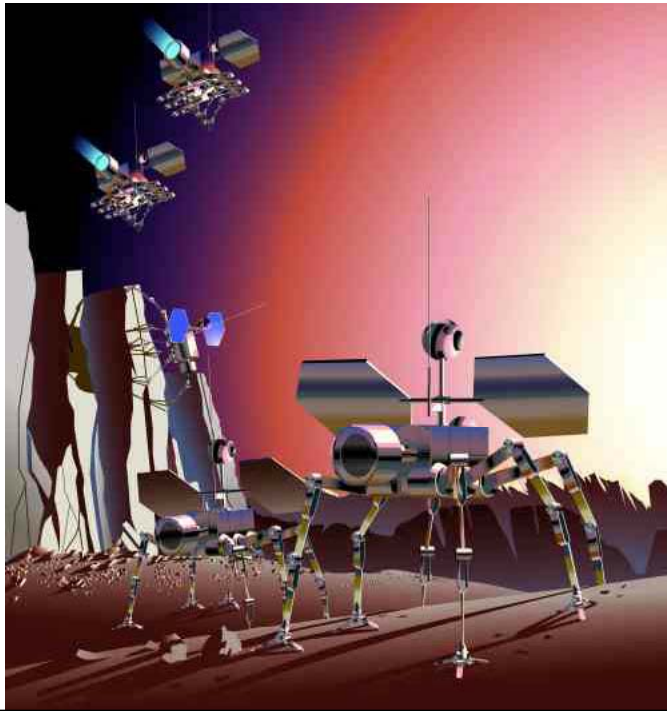


Ice skating on Enceladus... in virtual reality

“Night Glide”

Image by Pat Rawlings

Skating on Enceladus: Enceladus, the brightest moon in the Solar System, reflects more than ninety percent sun rays. Its water ice exterior and low gravity might provide an opportunity for refueling interplanetary space craft with hydrogen and oxygen. With Saturn filling the sky even the darkest nights would have the benefit of some reflected sunlight.
<http://www.patrawlings.com/search.cfm?detail=1006>



A fleet of tiny robotic explorers swarm across the rugged surface of Mercury

A final (off-topic) thought...
**Why not a NASA exploration
paradigm change?**

Old paradigm:

Contracts sent out for bid:

how much will it cost to build a robot
for NASA to send to Mars?

What's it worth to have your robot on Mars?



LynxMotion
robotic
hexapod

New paradigm:
Contracts sent out for bid:

how much will you **pay** to build a
robot for NASA to send to Mars?



Fischertechnik mobile
robot kit



The best off-road
vehicles on Earth...
or Mars!



Mattel Hot-wheels "Sojourner"



"Our SUV is the one for
serious rough terrain."



I-cybie
robotic
dog



Leggo Mindstorm



Sony Aibo